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ANALYSIS OF SGF2 SMOKE POT OIL AND RECOMMENDATION FOR REUSE

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ARMAMENTS COMMAND
ARMAMENT RDE CENTER

U.S. ARMY ARMAMENT RESEARCH, DEVELOPMENT AND ENGINEERING CENTER

Warheads, Energetics & Combat-support Armament Center

Picatinny Arsenal, New Jersey

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14. ABSTRACT

As part of the Army's on-going effort to implement resource recovery and reuse (R^3) during the demilitarization of obsolete and unserviceable conventional ammunition, an effort was undertaken to characterize and recommend uses for SGF2 oil currently in storage at various locations, either in smoke pot munitions or in separate containers. Samples of oil were extracted from smoke pot munitions and containers stored at three Army Depots. The oil was then subjected to a battery of tests in order to characterize it, determine its type and quality, and, based on this information, ascertain potential uses for it as a recycled material. Twenty-three oil samples were obtained, which formed the basis for this study: 22 from various smoke pot munitions and one from a 55-gal drum of bulk material. Tests preformed included density, kinematic viscosity, percentage water, water and sediment, heat of combustion, distillation range, flash point, trace metals, and ash. The oil was found to be highly refined, clean, and consistent, and similar to Number 4 boiler oil in weight and other physical properties, although it was recommended that the oil be filtered to remove water and sediment prior to reuse. Removal of the oil from the larger of the two smoke pot munition types sampled (AN-M7) and the 55-gal. drum was easy. Removal of the oil from the smaller grenade-like munition (M6) was extremely difficult. A cost effective, efficient process for removal of oil from each munition/container type must be developed.

15. SUBJECT TERMS
SGF2 oil, AN-M7 smoke pot munition, M6 smoke post munition, Demilitarization, Recycle, Reuse

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The authors acknowledge the technical expertise provided by various personnel from Sierra Army Depot, Hawthorne Army Depot and Crane Army Ammunition Activity.

The authors also acknowledge the technical expertise provided by Diana-Lynn Herbst at U.S. Army Tank-automative and Armaments Command (TACOM)-U.S. Army Armament Research Development and Engineering Center (ARDEC), Picatinny Arsenal, New Jersey and her team who collected the samples from the different sites for characterization.

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INTRODUCTION

The Army has the primary responsibility to demilitarize obsolete and unserviceable conventional munitions and energetic items currently in storage. Traditional methods of demilitarization include disassembly with simple recovery of materials, open burning (OB), open detonation, (OD) and conventional incineration. At present, these methods are still in use and account for most of the demilitarization of conventional ammunition that is accomplished. However, in the immediate future, because of environmental concerns, OB/OD may no longer be a viable option and conventional incineration, while available, will be constrained by permitting problems, limited applicability, and the fact that incineration ash is a toxic waste that must be buried in a hazardous landfill. In order to insure the continued ability to reduce the existing obsolete munitions stockpile, respond to future stockpile generation, and maximize resource recovery and reuse (CR^3), new, safe, cost effective, environmentally sound technologies are required. The recycling and reuse of obsolete and unserviceable munitions and energetic items allows for a more environmentally friendly method of demilitarizing these items, while at the same time identifying products that can be produced utilizing components/materials from obsolete munitions.

The Armaments Systems Processing Division (ASPD) at U.S. Army Tank-automative and Armaments Command (TACOM)-U.S. Army Armament Research Development and Engineering Center (ARDEC), Picatinny Arsenal, New Jersey has the responsibility for developing demilitarization and recycling processes for DoD munitions. For this effort GEO-CENTERS was tasked under contract DAAE30-00-D-1009, Delivery Order 29, by ASPD to characterize and recommend uses for SGF2 Oil, currently in storage at various locations, either in smoke pot munitions or in separate containers. In order to do this, it was required to characterize the oil in order to determine its type and quality, and then based on this information, ascertain the potential uses for the oil for recycling (e.g. boiler fuel, etc.).

PROJECT SCOPE

The scope of this project is to

- Sample oil from major storage sites for analysis
- Determine the physical and chemical properties of the oil
- Determine the relative consistency of the oil samples from location to location and lot to lot
- Recommend potential uses for the oil based on measured properties

PLAN

It was determined that three storage sites would be visited to collect and photograph a broad range of samples. Due to cost constraints, the sampling could not be "statistical"; however, every attempt was made to acquire a broad range of samples, which would be representative of the entire stockpile. In addition, duplicate samples would be collected at selected sites, as well as samples from identical lots stored at different storage sites.

An analytical testing firm specializing in the analysis and characterization of oil and lubricants would be consulted for guidance on the tests that would properly characterize this oil for potential reuse. The lab is

Analytical Testing Services, Inc.
P. O. Box 61
191 Howard Street
Franklin, PA 16323
Telephone: 814-432-7214
FAX: 814-432-9424

The lab recommended the following tests:

ASTM TEST	DESCRIPTION
ASTM D445	**Kinematic Viscosity at 40°C**
ASTM D2270	Viscosity Index
ASTM D95	Water in Petroleum Products by Distillation
ASTM D96	**Water and Sediment in Crude Oil** By Centrifuge Method
ASTM D240	**Heat of Combustion of Liquid** Hydrocarbon Fuels by Bomb Calorimeter
ASTM D93	**Flash-Point by Pensky-Martens** Closed Cup Tester, PM
ASTM D86	**Atmospheric Distillation of Petroleum Products**
ASTM D5185	Elemental Analysis by ICP
ASTM D189	Conradson Carbon Residue
ASTM D482	Ash Content

Those tests highlighted in **bold - blue** were considered essential.

Not all tests would be done on all samples. A list of the testing performed and the rational for the samples selected is given in the next section.

After testing, the data would be collected and analyzed. Of particular interest is the quality of the oil and its consistency from lot to lot. The testing lab would be consulted to help evaluate the type and quality of the oil and recommend potential uses based on the results obtained.

FIELD SAMPLING RESULTS AND OBSERVATIONS

Sample Selection

Personnel from TACOM-ARDEC searched the database of smoke pot oil munitions lots in the Demil account. Lots for sampling were chosen based on the quantity of oil available, the storage site of the oil, the munition (i.e., the container in which the oil was stored), and whether duplicate samples were available. Three storage sites were chosen for sampling as follows: Hawthorne Army Depot (HWAD), Crane Army Ammunition Activity (Crane), and Sierra Army Depot (SIAD). To insure

that sample integrity would be assured, sampling was done by the author (GEO-CENTERS) and Diana-Lynn Herbst (TACOM-ARDEC). A list of the lot numbers and locations for samples taken is shown in Table 1.

Table 1. Sample selection

Test Lab ID	Sample Number	Sample Site	Container *	Comments
8217	EAXO-85481-1-31-2	HWAD	Large	
8218	**GL-3-HAW-63**	**HWAD**	Large	**Dupl. at different site**
8219	EAXO-35481-56-8-6-53	HWAD	Large	
8220	EA-35481-40-9	HWAD	Large	
8221	EAXO-35481-48-13-6-53	HWAD	Large	
8222	EA-55600-311-7-3 /55	HWAD	Large	
8223	EA-1-14	HWAD	Large	
8224	EA-1-15	HWAD	Large	
8225	EA-1-16	HWAD	Large	
8226	EA-1-17	HWAD	Large	
8227	**EA-1-13**	**HWAD**	Large	**Dupl. at different site**
8228	**EA-1-13**	**SIAD**	Large	**Dupl. at different site**
8229	EA-55600-184-3	**SIAD**	Large	
8230	BATCH 3053 55 GAL	**SIAD**	Large	**55 Gallon drum**
8231	**OPI-1-4**	**SIAD**	**Small**	**Small containers**
8232	**OPI-1-5**	**SIAD**	**Small**	**Small containers**
8233	**2011-41-15**	**CRANE**	**Small**	**Small containers**
8234	**2012-81-1009**	**CRANE**	**Small**	**Small containers**
8235	**GL-3-HAW-63 #1**	**CRANE**	Large	**Duplicate at same site**
8236	**GL-3-HAW-63 #2**	**CRANE**	Large	**Duplicate at same site**
8237	**GL-4-HAW-63 #1**	**CRANE**	Large	**Duplicate at same site**
8238	**GL-4-HAW-63 #2**	**CRANE**	Large	**Duplicate at same site**
8239	**Mix 1 (from Large)**			

* Large = Floating Smoke Pot, SGF2, AN-M7; Small = Smoke Pot Oil, SGF2, M6

Samples were taken from three sites. Note that duplicate samples of the same lot were taken at Crane. Also, this same lot was sampled at Hawthorne (GL-3-HAW-63). In addition, EA-1-13 was sampled at Hawthorne and Sierra.

Sampling

Most of the samples were taken from smoke pots as described in SW050-AB-MMA-010 (Pot, Smoke, Floating, SGF2, AN-M7). In the tables, this munition (AN-M7) is described as a "large". A few of the samples were taken from smaller, "grenade like" munitions (Smoke Pot, Oil, SGF2, M6). These (M6) are referred to herein as "small". One sample was taken from a 55-gallon drum (designated Batch 3053 55 gal).

The AN-M7 smoke pot munition is about 12 inches in diameter and 13 inches high. There is a sealed fuel chamber crimped to the bottom of the pot. The fuel chamber (containing ammonium nitrate) is completely surrounded by oil. Burning of the fuel provides heat to vaporize the oil. A fuze embedded in the top of the fuel block is used to ignite the starter mixture. Ventholes in the top of the pot provide outlets for the smoke. The AN-M7 Smoke Pot Munition contains approximately 13.5 Lbs of SGF2 oil. Figure 1 shows a drawing of the AN-M7.

The M6 munition is grenade like. It is about 2.5 inches in diameter and 6 inches high. A tube runs down the center of the munition, which contains the fuel. This tube is surrounded by oil. A spring-loaded fuze ignites the fuel, which provides heat to vaporize the oil. The smoke exits through two holes in the top of the munition. These holes are sealed by pressure sensitive tape. Internal pressure dislodges the tape on ignition. The M6 Smoke Pot Munition contains approximately 110 grams of SGF2 oil. Figure 2 shows a drawing of the M6.

Photographs of the munitions sampled are shown in Figure 3.

Sampling of the large containers was relatively easy. The pots that were sampled, and other large pots, which were observed, were found to be in good condition. The pot had a removable port on its side. The pot was placed on its side with the port facing up. The plug in the port was unscrewed and about 1 liter of oil siphoned from the pot. See Figure 4. The plug was replaced. A production process for draining all the oil from the pot could be as simple as (1) placing the pot on its side, (2) punching a hole on the topside of the drum, and (3) punching another hole on the bottom side of the drum from which the oil is drained. This would leave the ammonium nitrate fuel block in the center of the pot and the fuse in the top of the pot undisturbed.

Sampling of the 55 gal drum was equally uncomplicated. The plug in the top of the drum was unscrewed and oil siphoned from the drum.

The small "grenade like" munitions were generally found to be in poor condition, showing large sections of rust. Sampling of the small containers was extremely difficult. First, the fuse was removed from the top of the case. The "grenade" actually is a metal container within another metal container. The outside metal container is tightly attached to the inner container, which contains the oil and the ammonium nitrate. The outer metal container was "peeled" away with much effort. This exposed the inner container. See Figure 5. The drain plug was removed and a small hole punched in the other side of the container and the oil drained into the sample vial. Removal of the fuse often left residual black powder in the hole, which contaminated the oil when poured into the vial. Not much oil is found in these containers.

In a production Demil process, all of the recoverable oil would likely be mixed and filtered into large batches or lots. To simulate this, a mixture of all of the lots sampled was made and designated Mix 1.

Physical Description of Oil

A physical description of each oil sample is shown in Table 2.

Table 2. Physical description of oil samples

Test Lab ID	Sample Number	Sample Site	Physical Description
8217	EAXO-85481-1-31-2	HWAD	Golden Yellow
8218	**GL-3-HAW-63**	**HWAD**	Golden Yellow
8219	EAXO-35481-56-8-6-53	HWAD	Golden Yellow
8220	EA-35481-40-9	HWAD	Golden Yellow
8221	EAXO-35481-48-13-6-53	HWAD	Golden Yellow
8222	EA-55600-311-7-3 /55	HWAD	Golden Yellow
8223	EA-1-14	HWAD	Light Brown
8224	EA-1-15	HWAD	Light Brown
8225	EA-1-16	HWAD	Light Brown
8226	EA-1-17	HWAD	Light Brown
8227	**EA-1-13**	**HWAD**	Caramel
8228	**EA-1-13**	**SIAD**	Caramel
8229	EA-55600-184-3	**SIAD**	Light Brown
8230	BATCH 3053 55 GAL	**SIAD**	Golden Yellow
8231	**OPI-1-4**	**SIAD**	Yellow, Black Specs
8232	**OPI-1-5**	**SIAD**	Yellow
8233	**2011-41-15**	**CRANE**	Yellow
8234	**2012-81-1009**	**CRANE**	Green, Milky
8235	**GL-3-HAW-63 #1**	**CRANE**	Yellow
8236	**GL-3-HAW-63 #2**	**CRANE**	Yellow
8237	**GL-4-HAW-63 #1**	**CRANE**	Yellow
8238	**GL-4-HAW-63 #2**	**CRANE**	Yellow
8239	**Mix 1 (from Large)**		

Generally, the oil from the large containers ranged from yellow to light brown and was free of sediment and other obvious contaminants. The oil in one of the small containers was light green in color and milky and another sample contained small black flecks.

ANALYTICAL RESULTS

Tests performed include density, kinematic viscosity, percentage water, water and sediment, heat of combustion, distillation range, flash point, trace metals and ash. Limited number of analyses could be done on samples taken from the small containers due to limited amount of sample available. The data provided by these tests best define the type and quality of the oil.

The density of the oil was determined by pynchnometry and was found to be 0.9061 g/cc with a standard deviation of 0.0071.

Tables 3, 4, and 5 show the results for the other tests performed.

Table 3. Viscosity, Water, Sediment, Heat of Combustion, Flash Point

Test Lab ID	Sample Number	Kinematic Viscosity, F	Viscosity Index, F	Water, %	Water & Sediment	BTU/lb *	Flash Point, C
8217	EAXO-85481-1-31-2	21.07		Nil	0%	20975	
8218	**GL-3-HAW-63**	19.66		Nil	0%	21755	174
8219	EAXO-35481-56-8-6-53	20.13		Nil			170
8220	EA-35481-40-9	20.33		Nil			172
8221	EAXO-35481-48-13-6-53	19.08		Nil			168
8222	EA-55600-311-7-3/55	20.18		Nil			166
8223	EA-1-14	27.80		Nil	0%	21504	170
8224	EA-1-15	28.86		Nil			168
8225	EA-1-16	22.85		Nil			166
8226	EA-1-17	22.81		Nil			164
8227	**EA-1-13**	26.11		Nil	0%	21750	174
8228	**EA-1-13**	24.77		Nil	0%	20627	164
8229	EA-55600-184-3	19.30		Nil			166
8230	BATCH 3053 55 GAL	19.95		Nil	0.1%	20558	168
8231	**OPI-1-4**			Nil	0%		
8232	**OPI-1-5**			Nil	0%	18380	184
8233	**2011-41-15**			Nil	0%	21284	182
8234	**2012-81-1009**			Nil	0%		178
8235	**GL-3-HAW-63 #1**	19.73		Nil	0%	21762	174
8236	**GL-3-HAW-63 #2**	19.87		Nil	0%	21450	168
8237	**GL-4-HAW-63 #1**	19.77		Nil	0%	21793	178
8238	**GL-4-HAW-63 #2**						174
8239	Mix 1 (from Large)	3.71 / 21.47	15	Nil	0%	21629	

* Heat of Combustion.

Table 4. Distillation Range

Distillation Range												
Test Lab ID	**Sample**	**5%**	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**95%**
8217	EAXO-85481-1-31-2	574	607	644	668	689	708	728	750	779	826	867
8218	**GL-3-HAW-63**	582	609	643	667	688	707	726	747	775	829	880
8219	EAXO-35481-56-8-6-53	562	595	633	661	683	705	727	754	789	841	883
8220	EA-35481-40-9	564	596	635	661	683	705	728	755	789	841	882
8221	EAXO-35481-48-13-6-53	571	600	636	662	683	703	723	744	774	830	877
8222	EA-55600-311-7-3/55	562	595	633	660	682	704	726	753	787	839	879
8223	EA-1-14	552	595	646	682	713	742	772	801	834	877	915
8224	EA-1-15	555.3	598	647.5	682.6	713.7	742.9	771.9	801.3	833.2	873.1	907
8225	EA-1-16	564	600.2	641.5	669.2	692.6	713.7	734.8	757.2	785.2	827.4	864.6
8226	EA-1-17	564	599.8	641.1	339.2	692.3	713.4	734.1	756.5	783.7	825.5	862.4
8227	**EA-1-13**	553	593.9	641.1	674.6	703.8	731.8	760.7	791.1	824.4	866.9	902.6
8228	**EA-1-13**	553.8	593.5	638.4	670.7	698.4	725.6	753.8	784.5	818.2	861.6	896.7
8229	EA-55600-184-3	550.4	585.8	625.2	652.3	674.2	695	716.1	740.2	772.3	823	865.8
8230	BATCH 3053 55 GAL	569.3	600.2	633.6	655.3	673.4	690.3	707.6	726.8	749.5	781.5	807.5
8231	**OPI-1-4**											
8232	**OPI-1-5**											
8233	**2011-41-15**											
8234	**2012-81-1009**											
8235	**GL-3-HAW-63 #1**	575	601	635.2	659.9	680.3	699.2	718	737.9	765	816	862.4
8236	**GL-3-HAW-63 #2**	573.1	599.5	633.2	658.4	678.8	698	716.8	736.8	763.8	815.6	862.4
8237	**GL-4-HAW-63 #1**	573.9	600.2	634.4	659.2	679.6	398.8	717.2	737.5	765	816.3	863.1
8238	**GL-4-HAW-63 #2**											
8239	Mix 1 (from Large)	563.6	596.9	635.6	662.3	684.9	706.5	727.9	752.6	785.2	833.6	872.8

Table 5. Trace Metals and Ash

Test Lab ID	Sample	D5185 ICP, ppm													D482
		As	B	Ca	Cd	Cr	Cu	Fe	Mg	Na	P	Pb	V	Zn	Ash
8217	EAXO-85481-1-31-2	<0.1	0.4	<0.1	0.2	<0.1	2.1	<0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	
8218	**GL-3-HAW-63**	<0.1	0.6	<0.1	0.8	<0.1	0.8	1.7	<0.1	0.4	<0.1	0.1	<0.1	0.4	
8219	EAXO-35481-56-8-6-53														
8220	EA-35481-40-9														
8221	EAXO-35481-48-13-6-53														
8222	EA-55600-311-7-3/55														
8223	EA-1-14	<0.1	0.8	<0.1	2.5	0.1	3.8	4.8	0.3	<0.1	<0.1	<0.1	<0.1	<0.1	
8224	EA-1-15														
8225	EA-1-16														
8226	EA-1-17														
8227	**EA-1-13**	<0.1	1.1	<0.1	2.1	0.1	2.9	5.6	0.3	<0.1	1.9	0.1	<0.1	<0.1	
8228	**EA-1-13**	<0.1	1.3	<0.1	1.4	0.1	0.6	10.9	0.2	<0.1	<0.1	0.1	<0.1	0.5	
8229	EA-55600-184-3														
8230	BATCH 3053 55 GAL	0.1	1.2	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	<0.1	0.2	<0.1	<0.1	<0.1	
8231	**OPI-1-4**	<0.1	0.1	26.0	3.0	<0.1	17.8	0.9	0.4	2.4	19.9	30.0	<0.1	6.3	
8232	**OPI-1-5**	<0.1	0.1	30.8	4.0	<0.1	22.5	5	0.5	0.7	19.2	46.4	<0.1	6.6	
8233	**2011-41-15**	<0.1	0.1	<0.1	0.8	<0.1	0.5	1.4	0.3	0.1	2.0	0.8	<0.1	<0.1	
8234	**2012-81-1009**	0.3	0.1	0.1	1.1	<0.1	4.7	1.2	0.1	0.1	8.9	34.7	<0.1	0.3	
8235	**GL-3-HAW-63 #1**	4.3	0.6	<0.1	<0.1	<0.1	4.5	1.3	0.2	0.6	<0.1	0.7	<0.1	0.9	
8236	**GL-3-HAW-63 #2**	0.4	0.5	<0.1	0.3	<0.1	2.2	12.8	0.2	0.3	10.1	0.5	<0.1	<0.1	
8237	**GL-4-HAW-63 #1**	0.4	0.5	<0.1	1.2	<0.1	1.1	1.4	0.2	0.1	<0.1	0.1	<0.1	<0.1	
8238	**GL-4-HAW-63 #2**														
8239	Mix 1 (from Large)	<0.1	0.6	13.3	2.1	<0.1	4.8	6.9	0.3	1.3	2.1	5.6	<0.1	1.6	0.01

DISCUSSION

Analysis of the data presented (in consultation with the Analytical Lab) in the tables above show the results to be very consistent across all of the lots tested, even for those samples that appeared to be contaminated. The oil is highly refined, as evidenced by the narrow distillation range, and clean, as shown by the general absence of sediment, water, and ash. There is little metal contamination, except in OPI-1-4, OPI-1-5, and 2012-81-1009. These were samples from the small containers that were contaminated with black powder while removing the oil. As might be expected, the results for Mix 1 are comparable to that of the individual lots.

The oil is closest in type to Number 4 boiler oil, which has a specification for maximum viscosity of 24, or alternatively, a light lubricating oil. In reality, the oil tested here is more refined and cleaner (hence higher quality) than typical Number 4 boiler oil. In addition to boiler oil, it could be considered for use as a light lubricating oil (sewing machine oil). Due to its cleanliness and consistency, it could be used as an emulsifier for herbicide applications. It could also be used as a roller lubricant (rolling oil), for example, in the hot processing of aluminum metal.

No matter what application is chosen, the oil should be filtered before use, to remove any residual water and sediment. This is standard practice in the oil industry.

CONCLUSIONS AND RECOMMENDATIONS

1. All of the objectives of this program were achieved.

2. SGF2 fog oil, found primarily in smoke pot munitions, was sampled at three storage sites and analyzed for type and quality, in order to be able to determine possible uses for the oil. The oil was found to be highly refined, clean, and consistent, and similar to Number 4 boiler oil in weight and other physical properties. Based on the broad range of samples taken here and the analytical results presented herein, it is concluded that oil can be drained from containers and mixed into larger batches (e.g. 55 gallon drums) without any detrimental effect on oil quality. Consistent properties, and hence performance, from batch to batch can be expected. The recovered oil must be filtered to remove water and sediment before use.

3. Removal of the oil from the large smoke pots and the 55-gallon drum was easy. Removal of the oil from the small, grenade like munitions was extremely difficult. A cost effective, efficient process for removal of oil from each munition/container type must be developed. This was outside of the scope of this task.

4. It is recommended that a recycler be contacted for disposition of the oil. The data collected here suggests that SGF2 oil could be used as Number 4 fuel oil, or light lubricating oil, machine oil, roller oil, or emulsifier for herbicide applications. The data collected here, when combined with the experience and knowledge of the recycler, will help determine the most appropriate application(s).

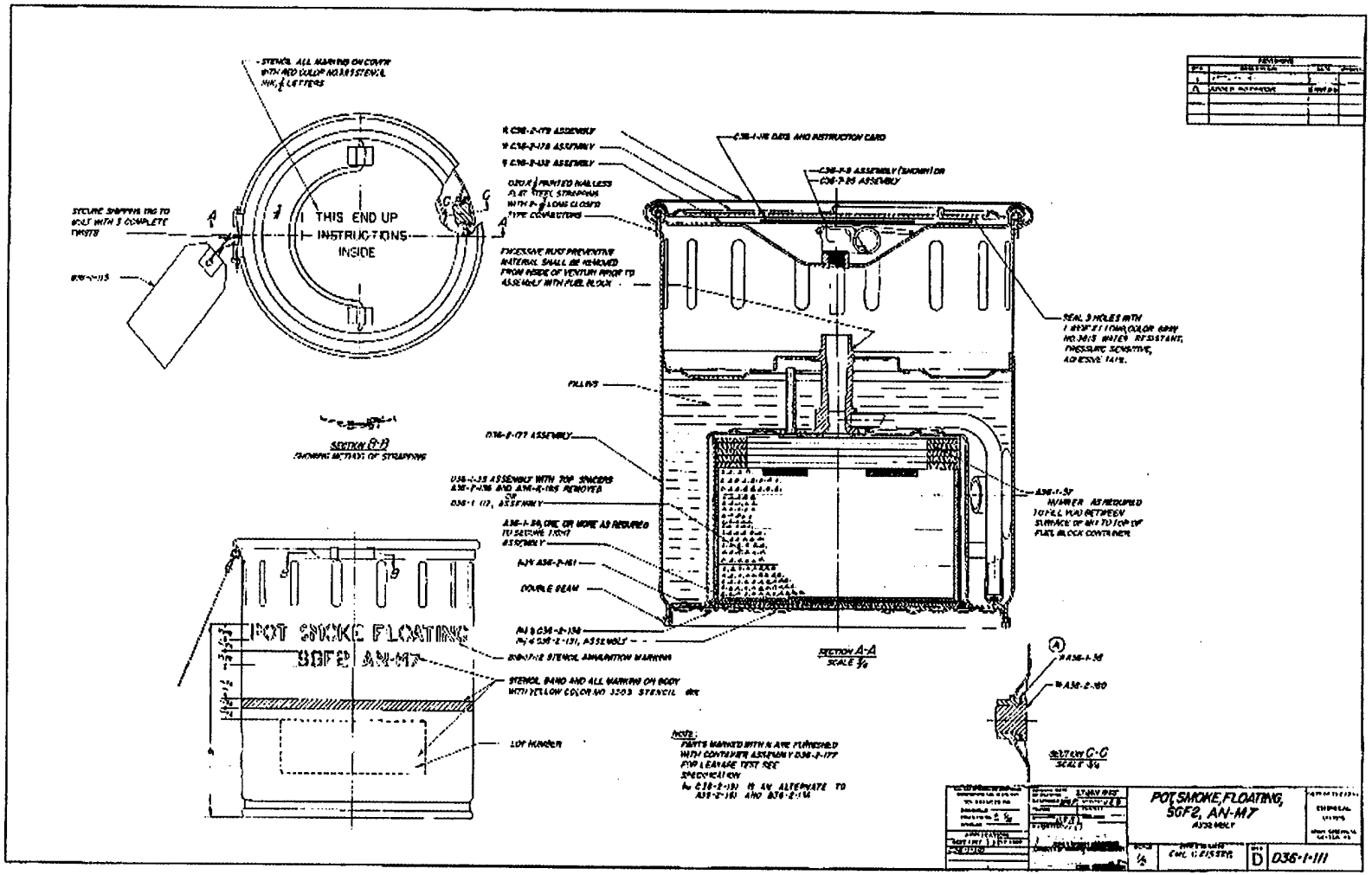


Figure 1
Drawing of AN-M7 munition

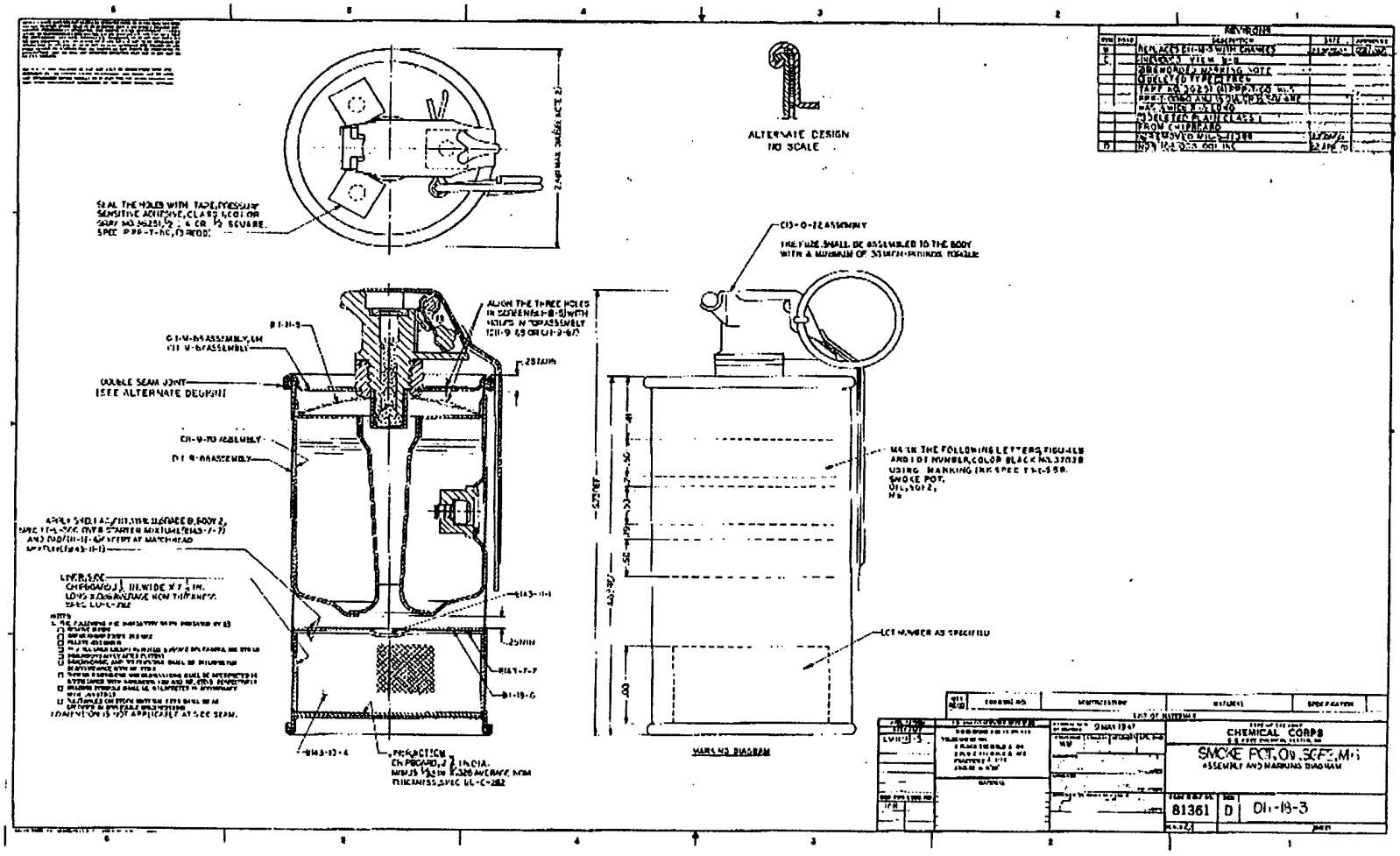
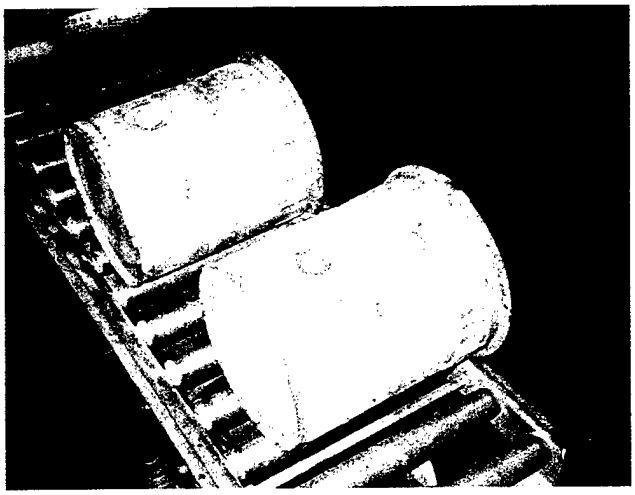


Figure 2. Drawing of M6 munition



AN-M7

M6

55 Gallon Drum

Figure 3. Photographs of smoke pot munitions/containers sampled

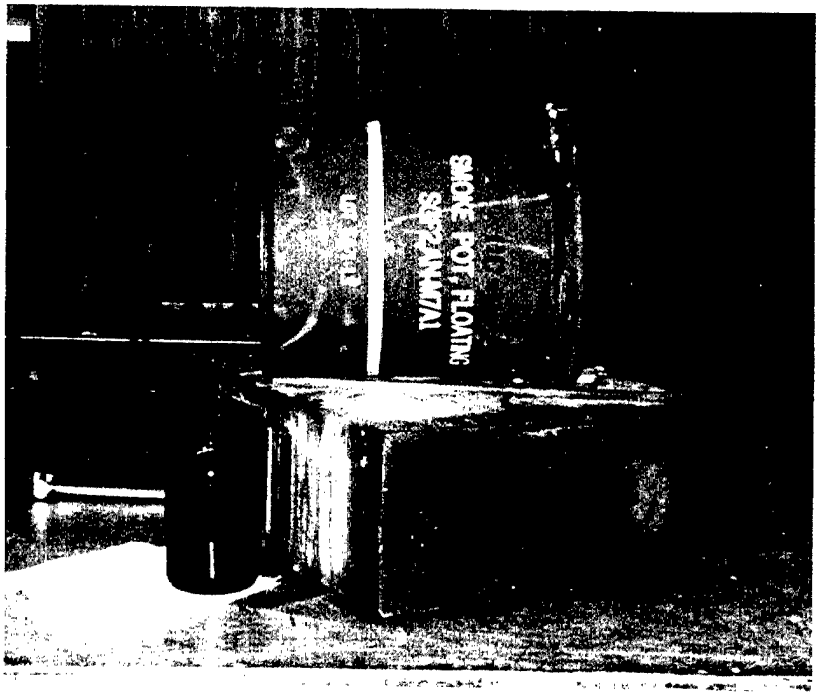


Figure 4. Photograph of AN-M7 munition being siphoned

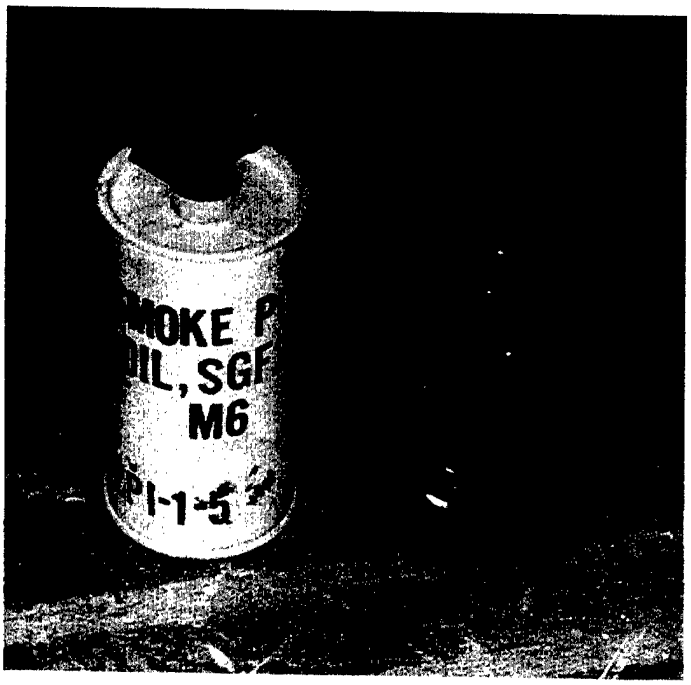


Figure 5. Photograph of inner container removed from M6 munition

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